LWG
LOWER WILLAMETTE GROUP

Portland Harbor Superfund Site

Technical Memorandum: Juvenile Salmonid Residence Time in Portland Harbor

DRAFT
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1.0 INTRODUCTION

The lower Willamette River provides habitat for fish from four Evolutionarily Significant Units (ESUs) of anadromous salmonids listed as threatened under the Endangered Species Act (ESA). Portland Harbor is an important migration corridor for anadromous salmonids, with adults moving upriver to spawning grounds and juveniles moving downriver to the ocean. Some areas of Portland Harbor may also provide rearing habitat for emigrating juveniles. The juveniles are considered the more vulnerable life stage with respect to potential impacts of contaminated sediments because they may feed on benthic organisms during their migration through the harbor and thereby ingest contaminants accumulated by these organisms. There is the potential for contaminant uptake by the juvenile salmonids if their prey has accumulated contaminants from the sediments. Assessment of potential risks to downriver migrants requires information on the amount of time spent in the area of contamination (residence time), food habits, and consumption rates. Most of this information is lacking for Portland Harbor.

This report provides the results of reconnaissance-level studies conducted in spring 2001 on the residence time of subyearling juvenile salmonids in Portland Harbor. This work is required by the U.S. Environmental Protection Agency (EPA) under the Administrative Order on Consent (AOC) signed by EPA and members of the Lower Willamette Group.

Some preliminary estimates of residence time of spring chinook salmon yearlings and steelhead trout smolts for Portland Harbor were developed by Oregon Department of Fish and Wildlife (ODFW) researchers in the late 1980s and early 1990s. Through the use of radio telemetry techniques, the ODFW researchers found that the mean rate of downriver movement of radio-tagged spring chinook salmon yearlings through the 12 miles of harbor (defined in their study as RM 0.0 to 12.0) ranged from 1.7 to 2.0 days (Knutsen and Ward 1992). The mean rate of downriver movement for steelhead smolts through the harbor ranged from 1.2 to 1.5 days. Subyearling chinook salmon movement through the harbor was not studied by ODFW, but it was suggested that these smaller fish might move at a slower rate than the substantially larger yearling chinook and 2-year-old steelhead (Knutsen and Ward 1992). Until recently, no further attempts to estimate rates of movement of juvenile salmonids through Portland Harbor have been attempted.

In 2000, the City of Portland initiated a 4-year investigation of fish use of the lower Willamette River from Willamette Falls to the mouth. The primary objective of the study is to evaluate habitat use by salmonids and other important fish species. The City's research team is using radio telemetry to evaluate habitat use by juvenile salmonids. Most of the radio-tracking effort to date has focused on yearling chinook, yearling coho, and steelhead smolts.

However, 13 subyearling chinook were tagged and tracked during the spring of 2001 along with 19 yearling chinook, 18 yearling coho, and 16 steelhead smolts. Mean migration rates in their study of juvenile salmonid cohorts ranged from 7.3 kilometers per day (kpd) or 4.5 miles per day (mpd) for sub-yearling chinook to 15.5 kpd (9.6 mpd) for steelhead smolts (North *et al.* 2001). Our study was coordinated with the City's study to ensure that the data developed by the two studies would be complementary.

Techniques for estimating residence time of subyearling chinook salmon in Portland Harbor are limited. The use of radio telemetry to track individual fish through the harbor has been demonstrated to work on large juveniles (> ___ mm FL) [This detail not included the ODFW report] (Knutsen and Ward 1992). However, radio-tags small enough to use on subyearling chinook salmon have become available only within the last two years. This study was conducted to evaluate the feasibility of using the miniature radio-tags (nanotags) for estimating residence time of the larger subyearling chinook salmon (107- 125 mm FL) in Portland Harbor. Emphasis was placed on testing the methodology and approach rather than trying to develop definitive estimates of residence time for subyearling chinook salmon. Specific objectives of the study were as follows:

- Test, evaluate, and refine proposed techniques for estimating residence time of subyearling chinook salmon in Portland Harbor.
- Develop a preliminary estimate of median residence time for radio-tagged subyearling chinook salmon in Portland Harbor, particularly within the site's Initial Study Area (ISA), which extends from river mile (RM) 3.5 to RM 9.5, during the period of peak downriver migration.
- Monitor ambient water quality (temperature, dissolved oxygen, conductivity, and turbidity) and flow conditions in conjunction with collection of fish movement and distribution data.

The information developed in this study will identify the best methods to study juvenile salmonids, and will provide preliminary information regarding residence time of subyearling chinook salmon in Portland Harbor.

2.0 STUDY AREA

This study was conducted in the lower Willamette River between RM 3.5 and RM 18.5 (Figure 1). Most of Portland Harbor, which extends from the river mouth to approximately RM 11.0, was included in the study area. The river reach from Swan Island (RM 9.5) downriver to Multnomah Channel (RM 3.5) was identified as an area of particular interest within the harbor because elevated sediment chemical concentrations have been identified within this reach.

Fish habitat conditions within the study area have been modified over the years by development in upstream areas of the watershed as well as by local urban and harbor development. The Willamette River has a channel length of 497 kilometers (309 miles), a drainage area of 29,785 square kilometers (11,500 square miles), and is the 13th largest river in the contiguous United States in terms of total discharge (Kammerer 1990). The river flows northward and is comprised of 13 major tributaries, which account for 93 percent of the drainage area. The mainstem reach from the mouth to Willamette Falls (herein referred to as the lower Willamette River) is tidally influenced, and flow reversals can cause intrusions of Columbia River water into the Willamette (Rickert 1984). The bed slope for the lower Willamette River is less than 0.019 m/km (0.1 ft/mi), and the depth approaches 37 meters (90 feet) at some locations.

Flows in the Willamette River are highly regulated by dams and reservoirs. Currently, there are 13 U.S. Army Corps of Engineers (USACE) reservoirs on major tributaries of the Willamette River. In addition to these USACE facilities, there are numerous small hydroelectric and irrigation facilitates located throughout the basin (Altman *et al.* 1997). Peak flows typically occur in December and January and low flows in late summer and early autumn.

The T.M. Sullivan Hydroelectric Plant, operated by Portland General Electric (PGE) at Willamette Falls, is the only hydroelectric project located on the mainstem. There are no dams or other fish passage impediments downriver of Willamette Falls on either the Willamette River or the Columbia River.

Water temperature data obtained by DEQ at the Burlington Northern Santa Fe (BNSF) railroad bridge (RM 7.0) indicates that the average monthly water temperatures for the Lower Willamette River are 11.1ºC during April and 14.4ºC during June, for the period 1995 through 2000 (no May data are available).

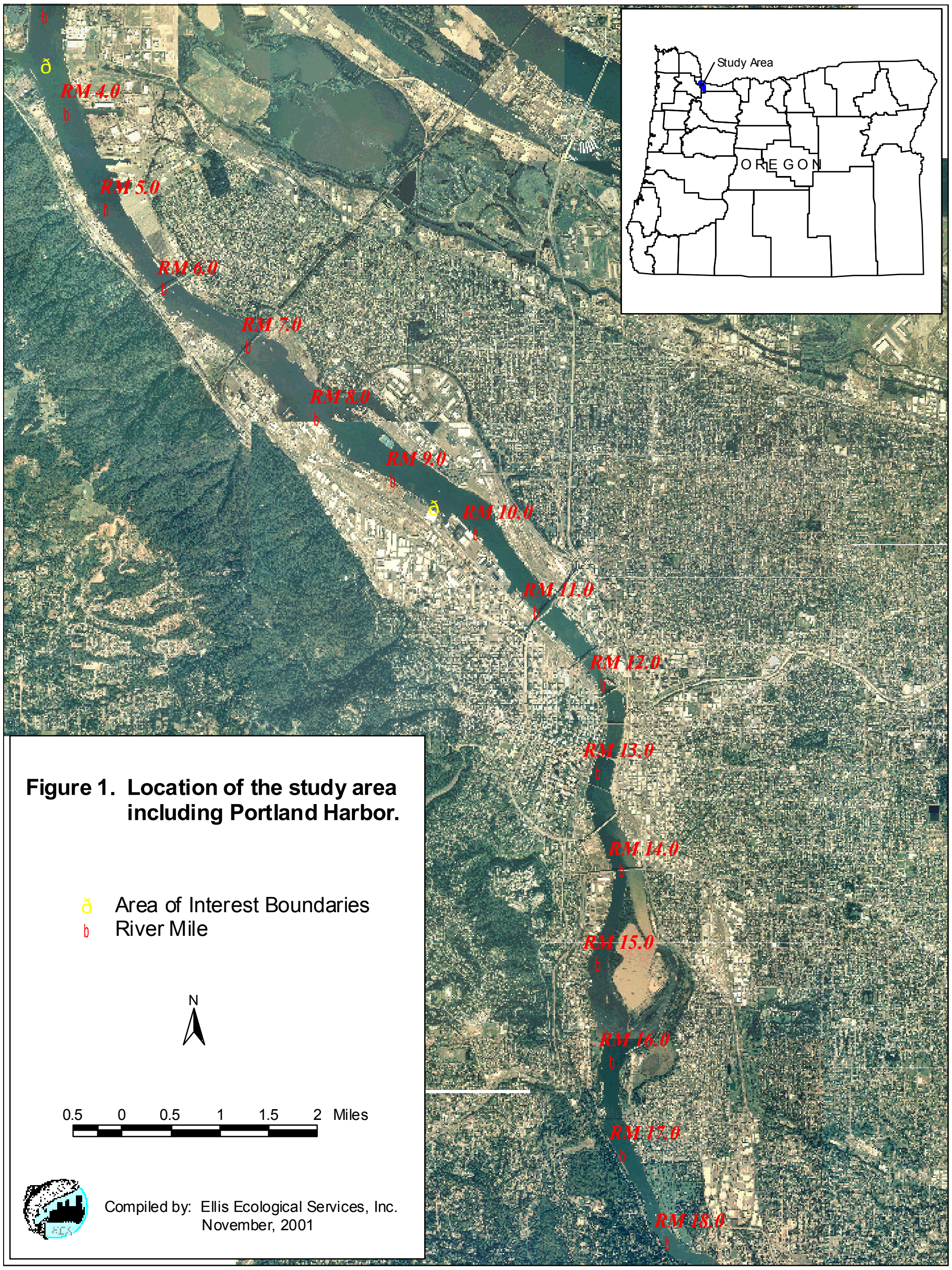

Figure 1. Location of the Study Area Including Portland Harbor.

Substrate composition of the lower Willamette River is characterized by sand, silt, and clay. Farr and Ward (1993) described the Willamette River bed in Portland Harbor as a silt and sand bottom. In a more detailed study of the main channel sediments, Fuhrer (1989) reported that their sediment samples consist of clay, silt, and sand with about 70 percent in the silt/clay category (<62 µm). Sediment samples collected from the lower Willamette River by Hart Crowser (2000) ranged from 32 to 98 percent sand (>75 µm) and from 2 to 68 percent silt (<75 µm).

The lower Willamette River mainstem is an important migratory corridor for salmonids and provides some rearing habitat for emigrating juveniles. Adult salmonids traverse the tidally influenced corridor during their upriver migration. Within Portland Harbor, little bank habitat remains that has not been altered by the construction of docks, wharves, or sea walls, or the placement of rock riprap. Channel width within the Harbor ranges from about 850 ft to 1,980 ft. The navigation channel within the ISA has been dredged to approximately 42 feet and its width limits the amount of shallow water rearing habitat (i.e., water shallower than –20 feet Columbia River Datum) to narrow strips along the east and west shorelines. Very few shoreline sites, clear of vegetation, debris, or piles, are available for effective beach seining.

The fish community of Portland Harbor consists of a variety of migratory and resident species. Sampling conducted by ODFW researchers from 1987 through 1990 identified 39 species from 17 families. Of the 39 species, 19 were identified as being exotic to the Willamette River. Relatively abundant resident species include common carp (*Cyprinus carpio*), largescale sucker (*Catostomus macrocheilus*), peamouth (*Mylocheilus caurinus)*, northern pikeminnow (*Ptychocheilus oregonensis*), black and white crappie (*Pomoxis* spp.), smallmouth bass (*Micropterus dolomieui*), and prickly sculpin (*Cottus asper*). Predator species known to occur in the harbor and prey on juvenile salmonids include the northern pikeminnow, smallmouth bass, and largemouth bass (*Micropterus salmoides*).

3.0 APPROACH

3.1 RESIDENCE TIME AND RATES OF TRAVEL

The study described herein should be considered a "pilot study" as the objectives were to test, evaluate, and refine proposed techniques, to determine residence time and monitor water quality. It is anticipated that this is the first year of a multi-year study. A relatively small number of fish were used, as efforts were primarily focused on methodology and not necessarily statistical inference. Preliminary estimates of residence time, rates of travel, and the variability associated with the estimates presented herein should be used with caution. Many factors that are known to influence the downriver movement of subyearling fall chinook, including year-to-year variability in flow and fish size, could not be accounted for in the 2001 study.

Capture efforts were timed to target wild subyearling fall chinook during their peak period of downriver migration. Subyearling or "ocean-type" fall chinook move downriver through Portland Harbor later in the season than do yearling or "stream-type" spring chinook. Generally, peak migration of the subyearling fish occurs in June while the peak migration for the yearling fish occurs in March and April (Knutsen and Ward 1992, Domina 1998). Mobile tracking during the 2001 study was conducted from late May through June.

A few of the fish used for radio-tagging were collected by beach seine in the lower Willamette River. However, most of the fish used for tagging were collected from the bypass facility located at the T.M. Sullivan Hydroelectric Plant. Fall chinook that spawn upriver of Willamette Falls are not included in the lower Columbia River chinook salmon ESU. Therefore, by using fish collected at the Willamette Falls bypass facility, we were able to reduce handling (i.e., "take") of listed juvenile fall chinook salmon.

Radio telemetry was used as the sole means of tracking the downriver movement of subyearling fall chinook. Radio telemetry techniques are limited by minimum fish size but do not require the recapture of fish after release. Instead, radio telemetry allows for mobile tracking of downriver movement through the use of a radio receiver and directional antenna.

The use of Passive Integrated Transponder (PIT) tags, which could be used on smaller subyearling fish (approximately 65 mm/2.6 in to 100 mm/3.9 in fork length), was originally proposed for the 2001 effort. However PIT tagging was not used because of permitting difficulties associated with the proposed use of an electrofishing boat for collecting fish.

All possible efforts were made during this study to minimize the effects of handling and surgery on fish physiology and behavior. Strategies were developed and used to reduce the number of times captured fish needed to be handled. Beach seining was conducted in an efficient manner, as fish were allowed to remain in the water while netted and quickly released if they were of an inappropriate size or species. Fish retained at the T. M. Sullivan bypass facility were held in chambers with river water running through them. During transport and before and after surgery, fish retained were held in 30-gal containers, in which the water was frequently exchanged with river water. During the 24-hr holding periods, the fish were retained in 30-gal perforated containers that were placed in the river. Dissolved oxygen was aerated into the containers during transport, surgical preparation, and recovery periods. Only green containers were used, as other colors are known to increase fish stress, and sanctuary nets (wet-bottom dip nets) were used to move fish from one container to another.

3.2 WATER QUALITY

Water quality conditions may affect residence time and, therefore, were monitored throughout the 2001 mobile tracking effort. Other than timing and flow, water temperature, turbidity, and dissolved oxygen concentrations are the most important parameters that likely affect the downriver movement of juvenile salmonids. These parameters also influence the recovery of radio-tagged fish after surgery. Conductivity is an important variable in radio telemetry effectiveness. The conductivity data will also aid in refining future boat electrofishing efforts, allowing the field crew to better predict the most appropriate electrofisher output settings (voltage, pulse width, and pulse frequency) to minimize fish mortality.

4.0 METHODS

4.1 SALMONID CAPTURE

Subyearling fall chinook salmon for use in the radio telemetry study were collected from the lower Willamette River. Some of the fish were collected by beach seine but the majority were collected from the screened bypass facility at Portland General Electric's T.M. Sullivan hydroelectric plant at Willamette Falls.

Beach seining was conducted on May 22-23, June 2, and June 15 prior to the first, second, and third releases of tagged fish, respectively. Seining was conducted on open beaches between the lower end of Ross Island (RM 14.1) and the mouth of Johnson Creek (RM 18.2). Sampling was limited to daylight hours. With the exception of the first release, we were unable to find sufficient numbers of fish large enough (i.e., >100 mm/3.9 in FL) for tagging. Nearly all of the subyearling chinook caught by beach seine were in the size range 55 mm (2.2 in) to 100 mm (3.9 in) FL. Due to the lack of larger fish, no attempt was made to collect fish for the fourth release by beach seining.

Beach-seined subyearlings of suitable size for radio-tagging were temporarily held in a 113.6-L (30-gal) plastic container partially filled with fresh river water. These fish were then transported by boat to an in-river holding pen. The holding pen consisted of four, 30-gal dark green plastic containers held together in a wooden plywood frame supported by floats. Each container was perforated to allow continual renewal of water during the holding period.

Subyearlings collected at the T.M. Sullivan hydroelectric plant bypass facility were obtained by dipnetting from a holding area in the bypass (Appendix A, Photographs 1-3). The bypass facility was installed in 1971 and is comprised of two portions: 1) the guidance area, and 2) the actual fish bypass. The guidance portion consists of a forebay training wall and a trash rack louver system that guides the fish past 12 hydroelectric turbine units. The majority of downriver migrants enter the bypass through the forebay to turbine 13. The entire penstock of turbine 13 is screened with an Eicher pressure tilt screen. From the screen, fish are diverted into a bypass conduit. The conduit leads to a plunge pool, then into an evaluation station, which can be set to pass fish directly to the tailrace or to detain the fish (Domina 1998). All fish were collected while the bypass was set to detain fish (sampling mode). Fish were dipnetted using a sanctuary net and were immediately transferred to nearby holding tanks. River water was circulated through the tanks to maintain temperature and dissolved oxygen levels.

PGE biologists studied descaling of fish passing over the Eicher screen during the period 1991 through 1995. The average descaling rate was found to be less than 1.5 percent for juvenile fall chinook salmon (Domina 1998). We visually inspected the fish that were transferred to the holding tanks for any signs of abnormal behavior or obvious descaling. Only healthy appearing fish were selected as potential tagging candidates.

The fish selected at the T.M. Sullivan bypass facility for potential tagging were transported by truck to a boat ramp at Milwaukee, Oregon (RM 18.5) and then loaded onto a boat to complete the trip to the holding pens. Pure oxygen was bubbled into the holding tanks during transportation from the bypass facility to the holding pens to maintain saturated dissolved oxygen conditions. Two holding pens (described above) were tethered in deep water a short distance from the boat ramp. All fish were held in the pens for 24-hrs prior to, and after surgery. During the first release in which only beach-seined fish were used, a single holding pen was tethered in a cove at Ross Island (RM 15.3). During all subsequent releases, two holding pens were tethered at the Milwaukee site.

4.2 SURGERY AND RELEASE

Miniature radio-tags (Lotek NTC-3 nanotags) were surgically implanted into the selected fall chinook 24-hrs prior to release. Each radio-tag weighed 0.86 g (0.03 oz, in air) and consisted of transmitter components encased in an inert resin capsule (6 mm/0.2 in x 15 mm/0.60 in) and a flexible antenna made of Teflon-coated stainless steel wire (0.5 mm/0.02 in diameter and 31.5 cm/1.2 in length). Fish were selected from the holding pens based on their size and condition. The weight of the miniature radio-tag represented 2.6 – 7.8 percent of the body weight of fish selected for study. The target tag weight-to-body weight ratio is generally two percent (Adams *et al.* 1998a). However, recent research at the Columbia River Research Laboratory in Cook, Washington indicates that ratios as high as six percent showed little indication of detrimental effects on behavior of juvenile salmon (D. Rondorf pers. comm. 2001). Selected fish ranged from 100 mm (3.9 in) to 152 mm (6.0 in) FL.

Procedures for surgical implantation of transmitters were similar to those used by Moore *et al.* (1990). All of the surgeries were performed in a mobile laboratory located a short distance from the river's edge (Appendix A, Photograph 4). Selected fish were removed from the holding pen using a sanctuary net and were anesthetized at the mobile lab in a green five-gallon container containing 70 ppm tricaine methanesulfonate (MS-222) buffered with sodium bicarbonate to a pH 7. Individual fish were retained in the anesthetic solution for approximately 30 seconds after losing equilibrium. A stopwatch was used to track time spent in the anesthetic as well as the time required for each operation. During surgery, the fish were placed on a soft foam pad with a groove cut in the center. The foam pad was covered in plastic and the plastic was sprayed with Stress Coat. The groove in the pad was used to stabilize the fish's body during surgery.

Surgeons from the Columbia River Research Laboratory who had extensive experience in radio-tagging juvenile salmonids performed all of the surgeries. Fish were placed ventral side up on the foam pad while the gills were flushed continuously with anesthetic (MS-222, approximately 20 ppm) fed through surgical tubing placed in the fish's mouth. An in-line valve was used to control the anesthetic flow. For each fish, a nano tag was activated and surgically implanted through a 10 mm (0.40 in) incision made parallel to the midventral line starting anterior of the pelvic girdle. A 3 mm (0.12 in) scalpel with a 15º blade was used to insure that the incision was only deep enough to penetrate the peritoneum. A 0.1 ml/g body weight dosage of oxytetracyclene was pipetted into the incision to minimize the chance for infection. An 18-gauge intravenous catheter and needle were used to guide the antenna through the body wall of the fish posterior and slightly caudal to the origin of the pelvic fins. Once the needle and plastic catheter pierced the skin of the fish, the needle was gently pulled out, leaving the catheter through the body wall. The transmitter's antenna was then threaded through the catheter and gently pulled toward the fish's tail while the transmitter was inserted into the body cavity. The catheter was then removed. The incision was closed with three simple sutures (5-0 Vicryl) evenly spaced across the incision. The antenna was attached to the side of the fish with a single suture slightly posterior to the exit site. A small amount of antibacterial ophthalmic ointment was applied to all incisions to prevent infection (Appendix A, Photograph 5).

Approximately one minute before completion of the surgical procedure, the flow of the anesthetic solution was replaced with freshwater to start the recovery process. After surgery, the fish were allowed to recover in a bath of oxygenated fresh river water, then placed back into the holding pens in the river. To avoid antenna entanglement, no more than three fish were placed in each of the 30-gal containers at the holding pens.

After a 24-hr holding period, radio-tagged fish were released into the Willamette River. Each holding pen was slowly towed by boat to the release site at mid river. Each container was carefully tipped on its side under water, and the tagged fish were allowed to swim out. Upon release, a telemetry receiver was used to verify that the radio-tags were on and working properly. The first release took place on May 25 just upriver of the Steel Bridge (RM 12.2) in Portland, Oregon. All subsequent releases took place at RM 18.3, near Milwaukee, Oregon. Release two occurred on June 4, release three on June 17, and release four on June 24.

4.3 MOBILE TRACKING AND WATER QUALITY MONITORING

The locations of radio-tagged fish were periodically recorded as they moved downriver towards the Columbia River. Tracking was accomplished by two 2-person crews using an 2.4-m (8-ft) boat, equipped with a SRX_400 telemetry receiver made by Lotek Engineering, Inc. and a Cushcraft four-element yagi (aerial antenna) designed for a frequency range 146-150.5 MHz (Appendix A, Photograph 7). One crew tracked fish from 0700-hr to 1600-hr and the second crew tracked fish from 1900-hr to 0400-hr during each 24-hr period throughout the duration of the four tracking periods. A second boat (6.1-m/20-ft jet sled), identically equipped for mobile tracking, also was used during intensive search operations and as backup for the primary tracking boat. Intensive searches with both boats generally occurred during the first 12 hrs after the tagged fish were released and when conditions made it difficult for a single crew to locate tagged fish.

Mobile tracking crews were trained on the lower Willamette River using test “drogues” made of 10-ft and 20-ft sections of ¾ inch PVC pipe. The sections of pipe were capped and weighted such that they would float vertically in the upper water column. An active radio-tag was attached at the weighted end of each drogue and allowed to drift freely with the current of the river. Once a drogue was released at a location unknown to the tracking crew trainees and allowed to drift for approximately 10 minutes, the crew initiated a search pattern until the drogue was located. This procedure was repeated several times until each member of the tracking crew demonstrated a proficiency at finding the test drogues and recording the appropriate data.

The telemetry receivers were programmed prior to each release to scan the appropriate frequencies of the surgically implanted radio transmitters (nanotags). The nanotags were set at the factory with a four-second burst rate and were estimated to have a 14-day life span. Several search patterns were developed for varying search intensities and selected for use by the crew leader depending upon the amount of river area requiring the search, time available to conduct the search, number of boats conducting the search, weather, and water conditions. The most prevalent search pattern utilized was a tight zigzag pattern, moving the boat from one side of the river to the other, while continuously and slowly rotating the yagi antenna a full 360 degrees. The receiver would scan a maximum of four frequencies for a five second duration each. During the search, the boat(s) would travel approximately six miles per hour (mph). Once the technician operating the receiver heard a transmitter signal he would lock onto the heard frequency and direct the boat operator to steer towards the signal using the directionality of the signal strength. As the boat approached the signal and signal strength increased towards its maximum power, an underwater antenna was then deployed and used to verify the signal location. A Trimble GeoExplorer 3 Global

Positioning System (GPS) was used to record the coordinates of the fish's location. A data dictionary and menu driven data collection system were developed and programmed into the GPS unit to facilitate consistent data collection techniques and to minimize data entry errors. Hand written field forms were also used to duplicate data collected in the field for backup and verification. Once the data were recorded in the GPS unit and on a handwritten field form, the mobile tracking crew continued their search for other transmitter signals.

Our mobile tracking crews periodically collaborated with the ODFW mobile tracking crews while on the river and exchanged information regarding search techniques, equipment adjustment, and water conditions. Coordination was also maintained between project managers throughout the 2001 study efforts. After our second release, the ODFW crew programmed our radio-tag frequencies into their fixed radio telemetry receivers located within the lower portion of Portland Harbor. The ODFW crew provided length/frequency and catch per unit effort data from their beach seine and electrofishing efforts in the lower Willamette, which aided our understanding of migration timing and available size classes.

An YSI Model 85 multi-parameter water quality probe was used to collect dissolved oxygen, conductivity, and water temperature at random locations throughout a work shift. The probe was calibrated for dissolved oxygen measurements in a water-saturated air environment at an altitude of 50 ft above mean sea level. Temperature readings were verified periodically with a standard mercury thermometer. Turbidity samples also were collected concurrently and analyzed using an Orbeco-Hellige Model 966 portable turbidimeter. The turbidity meter was calibrated to zero and 40.0 nephelometric turbidity units (NTU) using primary standards supplied by the manufacturer. Water quality data were recorded using the menu driven data collection system programmed into the GPS units and handwritten field forms.

4.4 DATA ANALYSIS

Data were downloaded periodically from the GPS units, differentially corrected (using US Forest Service base station data from Portland, Oregon), and projected from geographic coordinates to the state plane coordinate system. Handwritten field forms also were collected periodically from the field crew to accompany the GPS data. Positional data were used immediately after periodic downloads to communicate and correct any data entry errors with the field crew and to predict the locations of individual fish during mobile tracking operations.

Once all of the data had been differentially corrected, projected, and compiled, quality assurance checks were made using digital aerial photography for positional data and the handwritten field forms for numeric and categorical data. The resulting spatial database was stored using geographic information system (GIS) software (ArcView 3.2). This spatial database consisted of individual spatial layers including the release location points, radio tracking location points, and water quality location points. Using digital raster graphics (scanned USGS 7.5' quadrangles) the centerline of the lower Willamette River and each RM were digitized from the mouth of the Willamette River (RM 0.0) to Willamette Falls (RM 27.0) to create additional data layers.

An exact river mile was assigned to each release point, radio tracking point, and water quality point using a spatial analysis process known as dynamic segmentation. Using ArcInfo 8.1 tools, a route was created along the centerline of the lower Willamette River using the RM data points as controls. The point data exported from GPS was compared to the route to derive an exact river mile for each location. The resulting river mile data were then added back into the project database as an additional field by joining on a unique record identifier. These data were exported to EXCEL spreadsheets for further analysis.

The spatial data were displayed and visually inspected for fish behavior in ArcView as the layers were queried for individual fish. Behavioral patterns identified during this visual inspection included mortality (indicated by a stationary signal) and an initial increase in the speed of downriver movement. Other less obvious behavioral patterns were observed including slow/fast downriver movement, upriver movement, stopping then continuing, circling, and edgewater/center channel movement. Location records were screened for those records that appeared to reflect mortality or an initial darting response following the surgery. The following rejection criteria were used to screen the location data:

- Telemetry data indicated that the fish had been stationary for more than four days (96-hrs).
- Telemetry data was insufficient to establish a rate of travel; the signal was tracked for less then one mile from the release site.

Only location records that did not meet the rejection criteria were used for rate of travel and residence time calculations. In addition, all three fish from the first release exhibited an initial increase in downriver movement (greater than twice the average rate of downriver movement) during the first 12-hrs after release, which extended into the ISA. These data were therefore considered suspect and were not used further in the analysis. Of the 43 fish released, 28 fish were located during the mobile tracking effort, 16 of which did not meet the rejection criteria and were used further in the analysis.

Rates of travel for the study area were calculated in EXCEL for each telemetry location by subtracting the RM associated with the release site and the RM at each location and then dividing the difference by the time it took for the fish to travel from the release site to the telemetry location point. For each of the 16 fish used in the analysis, the telemetry location furthest (in time) from the release was used to calculate the rate of downriver movement within the entire study area.

Rates of travel were similarly calculated for the ISA, however, the telemetry location data were again queried in ArcView for each of the 16 fish selected for the study area calculations and further screened for activity within the ISA. Only fish observed at several telemetry locations within the ISA, or immediately upriver and within the ISA, were used to determine residence time because of the behavioral variability and bias observed within the entire study area (Appendix D). Out of the 16 fish used for the study area calculation of downriver movement, only six fish had sufficient telemetry location data immediately upriver and within the ISA, or entirely within the ISA. For these six fish, the downriver telemetry data collected closest to the Broadway Bridge (RM 11.7) were substituted for the original release site and the last known location was used to calculate the rate of travel for the ISA. As there were not telemetry receivers fixed above and below Portland Harbor, residence time was simply derived from the rate of travel observed within the ISA.

The water quality data layers were also exported from ArcView to EXCEL and summarized for the entire study period. These data were used primarily to quantify river conditions that may have caused additional stress to the tagged fish. Water level data were acquired from the U.S. Geological Survey (USGS) for gauging station no. 14211720, located in Portland, Oregon.

5.0 RESULTS

5.1 OBSERVATIONS DURING FISH CAPTURE

Only a small number of fish were measured during the capture efforts to minimize the effects associated with handling. Therefore, no specific efforts targeted the quantification of fish size. However, fish captured during beach seine operations were noticeably smaller than those captured at the bypass facility. Fish captured in the beach seine ranged in size from approximately 55 mm (2.2 in) to 110 mm (4.3 in) FL while fish captured at the bypass facility ranged in size from approximately 80 mm (3.1 in) to 150 mm (5.9 in) FL.

5.2 RESIDENCE TIME AND RATES OF TRAVEL

A total of 43 fish were successfully radio-tagged and released in the lower Willamette River upriver of Portland Harbor in May and June 2001 (Appendix B). Of these 43 fish, 28 were located 266 times during the mobile tracking effort (Appendix C). None of our released fish were recorded on the ODFW fixed telemetry receivers. Fifteen fish were not located after release, and therefore the mobile tracking efforts were determined to be 65 percent effective in locating released fish. Sixteen subyearling fall chinook were selected (as previously described in section 4.4) and used to obtain a preliminary determination of mean rate of downriver movement. These 16 fish were located 147 times during the mobile tracking effort. Ten of these 16 fish were from release two, two fish were from release three, and four fish were from release four. Six out of the 16 selected fish had adequate telemetry to allow calculation of a residence time estimate for the ISA.

Within the entire study area (RM 3.5 to RM 18.5), the mean rate of downriver movement was 6.8 kpd (4.2 mpd). The standard deviation (SD) for the sample (n = 16) was 4.3 kpd (2.6 mpd). The median rate of downriver movement was 5.0 kpd (3.1 mpd). Figure 2 shows the radio telemetry locations for the radio-tagged fish representing the median rate of downriver movement. Travel rate among the 16 fish was highly varied (Table 1). Rates of travel ranged from 0.9 kpd (0.6 mpd) to 15.3 kpd (9.5 mpd). Residence time in the study area from RM 3.5 to RM 18.5 averaged 6.0 days (SD = 6.1 days, n = 16), ranging from 1.6 days to 26.9 days. The median residence time between RM 3.5 and RM 18.5 was 4.8 days.

The mean rate of downriver movement for the ISA (RM 3.5 to RM 9.5) was 4.5 kpd (2.8 mpd). The SD for the sample (n = 6) was 3.1 kpd (1.9 mpd). The median rate of downriver movement was 4.2 kpd (2.6 mpd). Residence time for the ISA averaged 3.4 days (SD = 2.5 days, n = 6), while the median residence time was 3.0 days. Rates of downriver movement in the ISA ranged from 1.4 kpd (0.9 mpd) to 8.1 kpd (5.1 mpd). Residence time for the ISA ranged from 1.2 days to 6.8 days.

Bathymetric data were used to divide those portions of the river that are considered shallow water rearing habitat, defined as water less than –6.1 m (–20 ft) CRD, and those portions of the river that are considered deep water habitat. No preference for shallow water habitat was observed between the Multnomah Channel (RM 3.5) and the Broadway Bridge (RM 11.7). All of the 16 fish selected were observed in this reach of the river during mobile tracking operations and located a total of 54 times. Only four of these 54 observations were located in shallow water rearing habitat (Figure 3). In addition, there was no correlation identified between fish size and rate of downriver movement and no diurnal effects were observed.

The 16 fish selected for use in the analysis of downriver movement rates for the entire study area averaged 115.2 mm (4.5 in) FL (SD = 5.3 mm/0.2 in) and averaged 15.0 g (0.5 oz, SD = 2.2 g/0.1 oz). Fork lengths for these selected fish ranged from 107 mm (4.2 in) to 125 mm (4.9 in), while their weights ranged from 11.3 g (0.4 oz) to 19.1 g (0.7 oz). The weight of the transmitter represented 4.5 percent to 7.6 percent of the body weight of these 16 fish. The six fish selected for use in the analysis of downriver movement and residence time within the ISA had an average fork length of 112.7 mm. The range in transmitter weight-to-body weight ratio for these six fish was identical to that of the 16 fish they were selected from.

5.3 FISH MORTALITY

A total of 12 fish died during the 24-hr post-surgery holding period (prior to release). This post-surgical mortality represented 22 percent of the total number of tagged fish. Necropsies were performed on three of the dead fish and blood clots were observed in the peritoneal cavity. The surgeons felt that at least part of the mortality was related to the small size of the fish. The same surgeons typically have seen mortality rates less than one percent during the 24-hr holding period for fish larger than 120 mm (4.7 in) FL. The transmitters were extracted from the dead fish and reused during the fourth release. During the third release, the antennas of two tagged fish became tangled during the post-surgery holding period and were separated by hand without apparent injury to the fish. None of the tags were expelled prior to release.

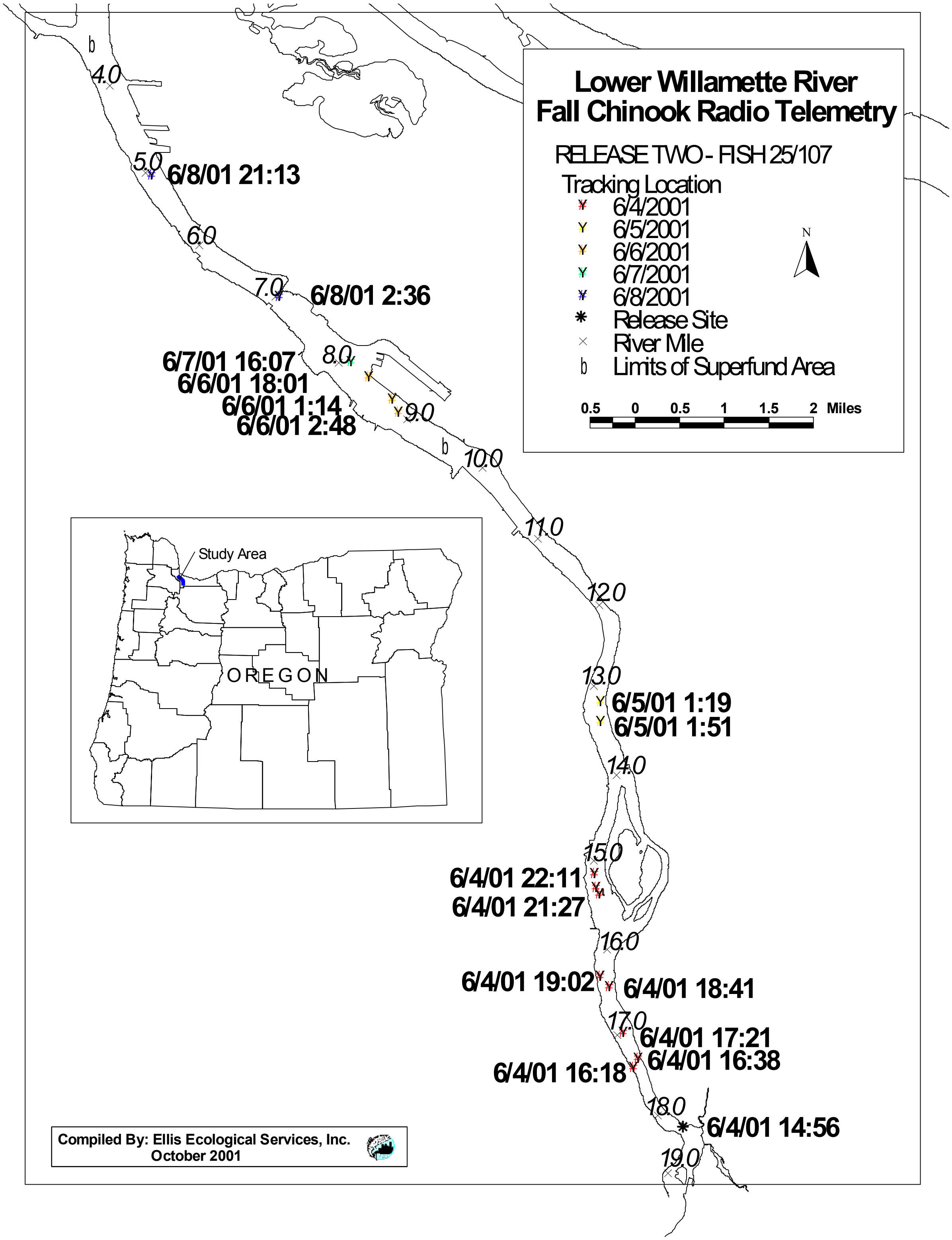

Figure 2. Downriver Movement of Median Radio-tagged Subyearling Fall Chinook Salmon.

Table 1. Summary radio telemetry data for subyearling fall chinook used for the preliminary determination of downriver movement rate of travel in the lower Willamette.

Release No.	Channel/ Code	Total Hours Tracked	Total Distance Tracked (mi)	Rate of Travel (mpd)	Fork Length (mm)	Weight (g)	Tag Weight Ratio (%)
2	10/107	403.0	9.4	0.56	113	13.7	6.3
2	10/108	137.1	13.4	2.35	107	11.3	7.6
2	10/109	130.8	9.7	1.78	108	12	7.2
2	10/113	23.4	9.2	9.48	125	18.3	4.7
2	15/108	51.2	10.0	4.70	119	16.5	5.2
2	15/110	70.2	9.2	3.15	116	15.5	5.5
2	15/112	32.1	11.9	8.90	112	14.4	6.0
2	25/107	102.3	13.3	3.12	113	14.2	6.1
2	5/110	58.3	7.4	3.03	112	12.9	6.7
2	5/112	54.3	13.3	5.89	115	14.5	5.9
3	25/114	197.9	13.5	1.64	122	19.1	4.5
3	5/107	79.4	5.5	1.66	119	18	4.8
4	10/112	12.2	2.8	5.51	110	13.6	6.3
4	10/116	23.7	6.6	6.73	120	14.9	5.8
4	15/117	94.8	11.0	2.79	111	13.9	6.2
4	10/117	27.5	6.7	5.85	121	16.4	5.2

Note: Grey shaded rows indicate those fish that were used for the calculation of ISA residence time.

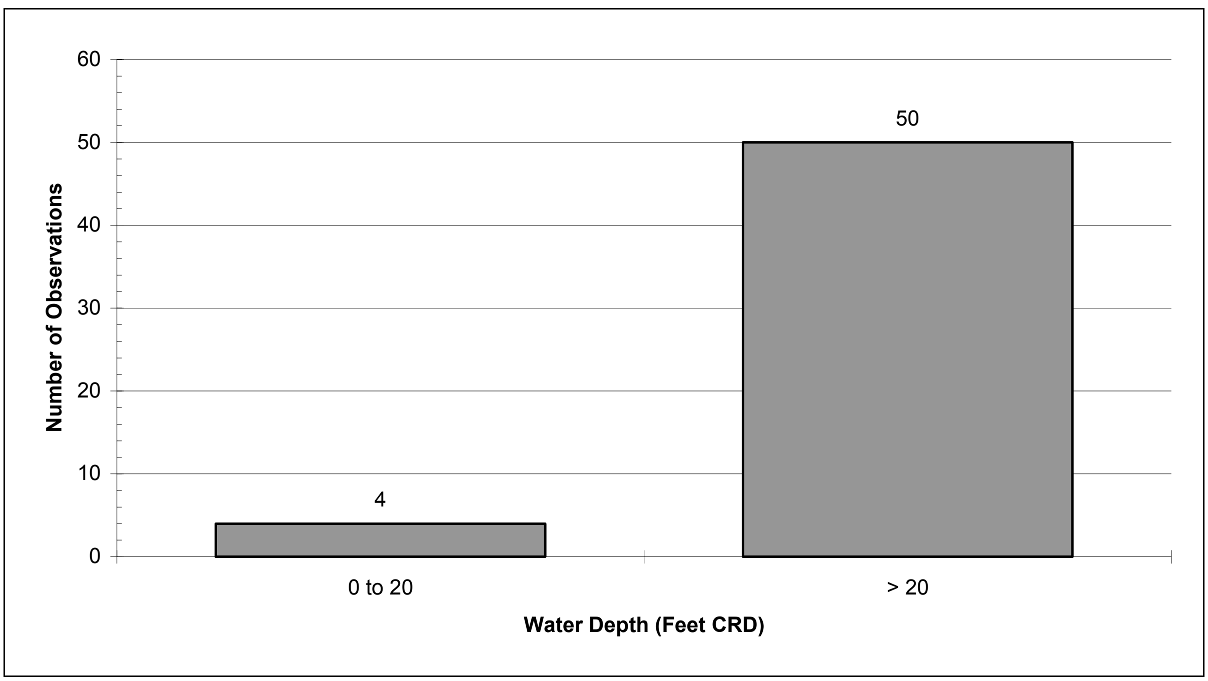

Figure 3. Number of observations of radio-tagged fish in shallow-water and deep-water habitats between RM 3.5 and RM 11.7.

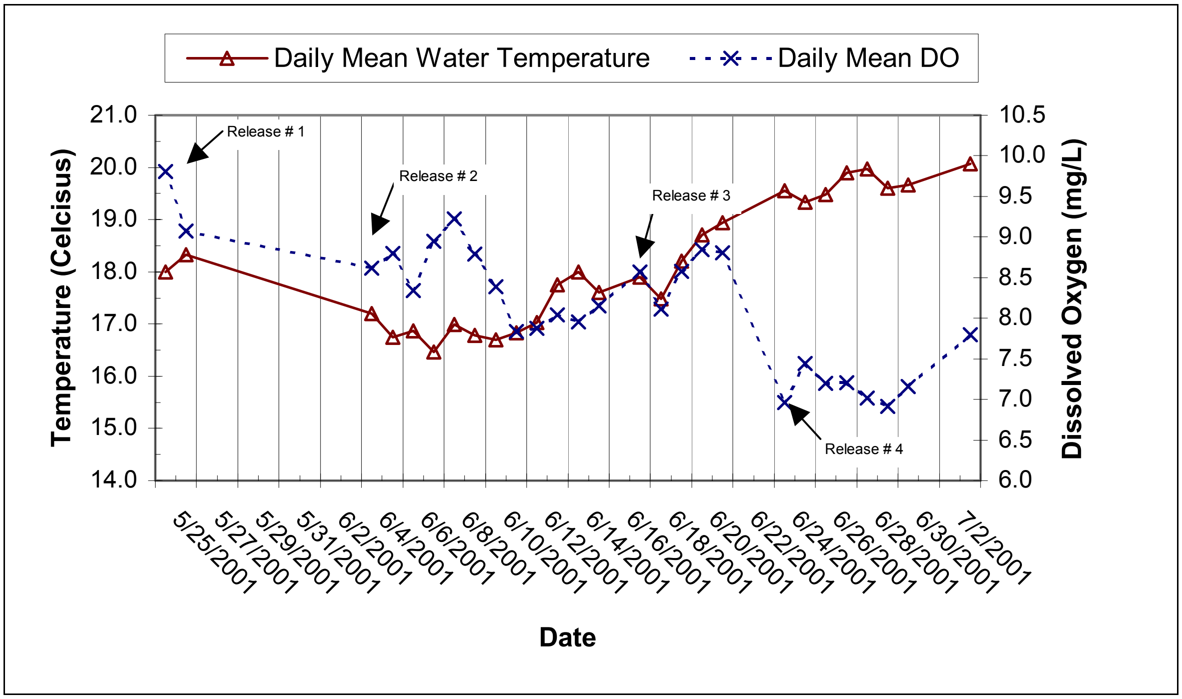

Figure 4. Daily mean water temperatures and dissolved oxygen concentrations.

5.4 WATER QUALITY

As would be expected in May and June, water temperatures generally increased over time during our mobile tracking efforts while dissolved oxygen concentrations decreased (Figure 4). Between May 25, 2001 and July 4, 2001, water temperature averaged 18.1°C (64.6°F), ranging from 16.0°C (60.8°F) to 20.6°C (69.1°F). Dissolved oxygen concentration averaged 8.1 ppm, ranging from 5.8 ppm to 9.8 ppm. Turbidity also increased slightly during this period of time, averaging 5.2 NTU and ranging from 2.6 NTU to 13.7 NTU.

Water levels in the Willamette River during the 2001 study period were unusually low. During our mobile tracking efforts, water levels fluctuated between 1.1 m (3.5 ft) and 1.9 m (6.2 ft) NGVD (Figure 5). Based on 14 years of data, water levels in the lower Willamette River at Portland, Oregon (USGS Gauging Station #14211720) during the same seasonal period average 2.9 m (9.5 ft) NGVD, while water levels in 2001 averaged only 1.5 m (4.9 ft) NGVD. The lowest water levels encountered during our study occurred during release 3.

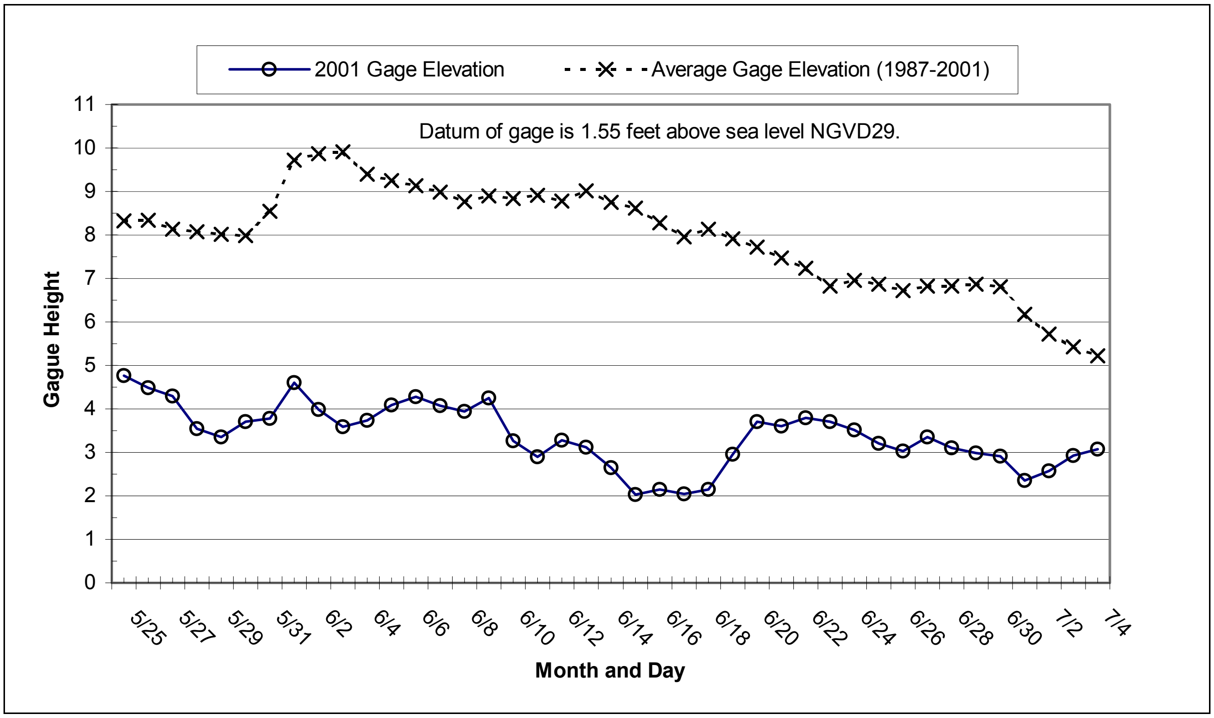

Figure 5. Lower Willamette River water levels at Portland, Oregon (USGS Gauging Station #14211720).

6.0 DISCUSSION

Very little is known about subyearling chinook salmon in the lower Willamette. Research on subyearling chinook migration in other areas suggests that they spend more time feeding than do larger yearling fish (Miller and Sims 1984, Knutson and Ward 1992). Radio telemetry methods, however, are limited by transmitter size, because adverse affects to fish physiology and behavior generally increase as the ratio of the transmitter weight to fish weight increases (Adams *et al*. 1998a). Subyearling fall chinook used in the 2001 study effort represented the upper end of the size range of subyearlings present in the lower Willamette River. Subyearling fall chinook range in size from approximately 30 mm (1.2 in) to 150 mm (5.9 in) and average around 80 mm (3.1 in, ODFW 2001 unpublished data). Fork lengths for the 16 fish used to determine residence time in this study ranged from 107 mm (4.2 in) to 125 mm (4.9 in) and averaged 115 mm (4.5 in). As smaller fish possibly move downriver slower than do larger fish, it is possible that our preliminary determination of residence time underestimates the amount of time subyearling fall chinook spend in Portland Harbor. During the 2001 study, we pushed the limits of recommended radio-tag weight-to-fish body weight ratios to account for this phenomena as best as possible given the limitation of available radio-tagging technology.

Radio transmitters are also limited by conductivity, transmitter frequency, and depth (Niezgoda *et al*. 1998). During our mobile tracking efforts, we were faced with significant challenges detecting radio signals under a variety of environmental conditions. Although conductivity was relatively consistent, interference from other radio signals, particularly in downtown Portland, and the depth of tagged fish at times impaired our tracking ability. A test of our ability to remotely detect a signal revealed that the detection distance decreased with water depth, ranging from a distance of 89 m (292 ft) while the tag was at a depth of 1.5 m (5 ft) to 8.5 m (28 ft) while the tag was at a depth of 12.2 m (40 ft) (Figure 6). This phenomenon probably severely reduced our ability to detect radio-tagged fish that migrated at depths greater then 6.1 m (20 ft). Other studies have shown that subyearling chinook salmon do occur in substantial numbers at depths greater than 12.2 m (40 ft) in the lower Willamette River (Knutsen and Ward 1992) and the Columbia River (Dauble *et al.* 1989). It is possible that some of the radio-tagged fish that were not found after release migrated through the study area at depths below those that could be detected by the radio telemetry receiver.

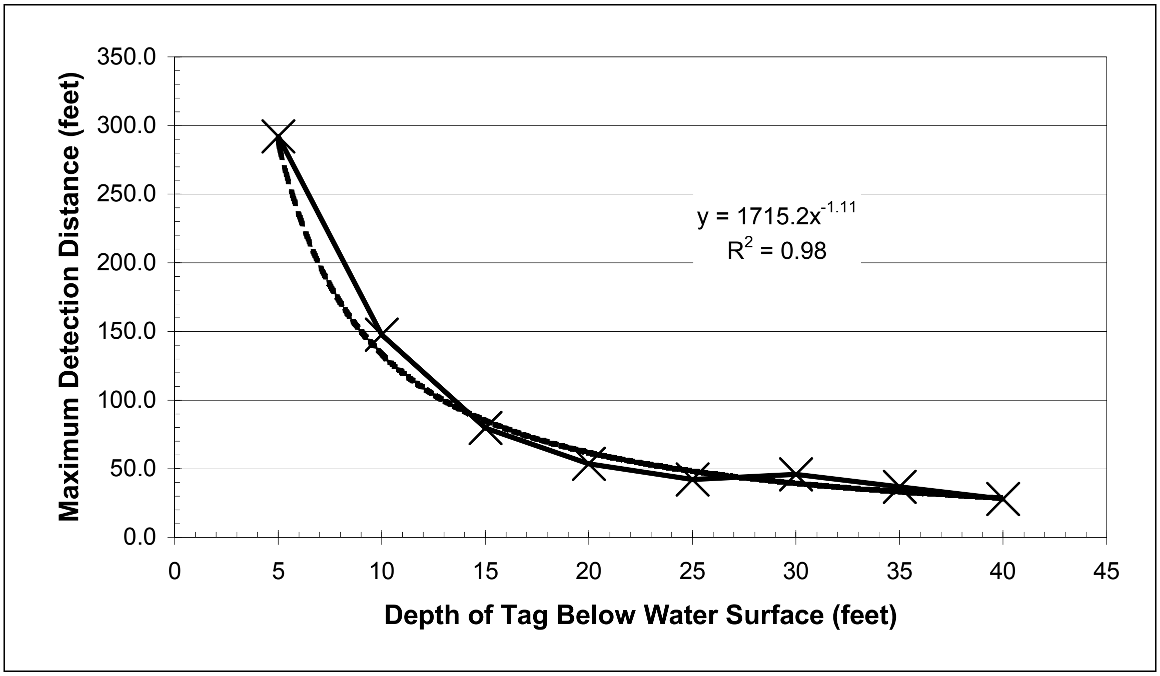

Figure 6. Ability to remotely detect a radio-tag at various water depths.

Predation may have been another factor affecting our ability to locate and/or analyze transmitter data. Some of the tagged fish may have expelled their transmitter after their release, became ill after release and died, or were the subject of predation (Appendix D). Based on our knowledge of fish behavior, we believe that predation of some radio-tagged fish did occur. Post-release telemetry data for some fish clearly show a rapid upriver movement followed by a stationary signal for several days. This type of behavior may indicate predation by resident and territorial fish such as bass. This observation and interpretation would be consistent with predation trials performed by Adams *et al.* (1998b) who found that fish with surgical implants were eaten by smallmouth bass (*Micropterus dolomieu*) in significantly greater numbers than controls. Factors that could have influenced the vulnerability of the radio-tagged fish to predation included 1) failure to rapidly detect predators, 2) a decrease in fast-start response, 3) inability to shoal effectively, and 4) increased conspicuousness (Mesa *et al.* 1994).

The effects of radio-tagging on juvenile salmon have been well documented. Fisheries scientists have recommended surgical implantation over other methods of radio-tagging (gastric implantation and external attachment) for extended studies of juvenile salmon because it least affects swimming performance, feeding, growth and physiological responses (Adams *et al.* 1998a, Jepsen *et al.* 2001, Martinelli *et al.* 1998). Generally, gastric tags are known to reduce feeding and growth of juvenile salmonids and external radio-tags impair swimming performance. Surgical radio-tagging is initially stressful for juvenile salmon, but the presence of the tags does not appear to be chronically stressful because cortisol, glucose, and lactate levels return to normal after a few days (Jepsen *et al.* 2001).

The rationale behind holding fish for 24-hrs prior to release was to allow a long enough period of time for initial recovery, and a short enough period of time to minimize the stress associated with holding actively migrating fish. This rationale has been used in many radio telemetry studies and appears justified through research regarding the effects of surgical transmitter implantation. Adams *et al.* (1998a) found that surgery impaired swimming performance of juvenile chinook salmon for one day after surgery. Stress measured through blood plasma cortisol levels also rapidly increases after surgery but appears to return to a normal range after a 24-hr period (Jepsen *et al.* 2001). During our radio telemetry efforts on the lower Willamette in 2001, we observed effects related to surgical radio-tagging consistent with those reported in the scientific literature. Within the 24-hr holding period after surgery, many fish appeared lethargic and some had difficulty maintaining neutral buoyancy. After the 24-hr holding period, fish that had survived the procedure appeared to swim efficiently and behave normally.

Water levels in the Willamette River were abnormally low during the 2001 study. It is commonly thought that the rate at which juvenile salmonids move downriver decreases as flow velocity decreases. Although many factors influence downriver movement, rates of travel are known to be somewhat correlated with flow regimes. Tiffan *et al.* (2000) found that flow explained 21-28 percent of the variation in travel rates. These findings are consistent with other studies of subyearling chinook travel time, and suggest that studies of residence time should span several years to account for year-to-year variability in river flow. Because flow levels were low at the time of the 2001 study, it is possible that our preliminary determination of residence time overestimates the amount of time juvenile salmonids spend in Portland Harbor.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 TELEMETRY

One of the primary objectives of this study was to test, refine, and evaluate the telemetry approach used in this study. Our results indicate that there are many factors that affected our ability to effectively track individual fish. One of the most important factors limiting our ability to track fish was water depth. The radio transmitters used in this study apparently do not have enough power to allow detection and readout when fish travel at depths greater than about 20 feet. Therefore, if subyearlings were to stay near the bottom of the river during their migration through the study area, the radio receiver would not detect them. Fortunately, many of the fish that were radio-tagged migrated downriver at depths that allowed reception and readout from a substantial distance. However, there were a number of fish that were never found after release. There may be several explanations why these fish were not found, including mortality, diminished signal strength due to a defective transmitter, or migration at depth greater than our detection abilities. Sub-yearling chinook have been shown to migrate at depths greater than 12.2 m (40 ft, Knutsen and Ward 1992, Dauble *et al.* 1989).

There is no easy solution to the depth problem. Miniaturization of the radio tags, to allow for tagging smaller individuals, has resulted in a reduction of output power. Until a miniature tag with more power can be developed, radio telemetry will be effective only in the relatively shallow layers of the water column.

The only potential telemetry solution to the depth problem would be the use of a sonic tag. Output from sonic tags can be picked up by hydrophones, which typically can detect tags from depths much greater than the depth of the Willamette River. However, at the present time, the smallest sonic tags are too large to use in subyearling chinook salmon. Lotek Wireless is developing a miniature sonic tag that will be about the same size and weight as the nanotags used in this study. These tags are in the development phase and may be ready for testing by Lotek Wireless clients in the spring of 2002. If these tags become available they could solve many of the reception problems inherent with use of radio tags in the urban environment of the lower Willamette River.

Mobile tracking of the radio-tagged fish from boats combined with GPS positioning was a satisfactory method for obtaining data on the tagged fish that migrated primarily in the upper water column. Reception problems were encountered between the Ross Island Bridge and the Broadway Bridge.

Apparently, radio-wave interference in the midtown area was higher than other areas and interfered with radio tag reception.

The fixed-site radio receivers set up by ODFW failed to record any of our tagged fish. Suitable locations for fixed sites are limited in the lower Willamette River and water depth and distance probably limits the effectiveness of fixed-site receivers. From discussions with ODFW personnel, they believe that more up-front work would be required in setting up the fixed site-receivers than they were afforded this past year. If sonic tags become available in the near future, fixed site receivers would probably be very effective in recording the sonic tagged fish.

Mortality of tagged juvenile salmonids following surgery was substantially higher than the surgeons typically encounter when tagging larger salmonids. This indicates that the stress of the tagging operation may be more significant on the subyearlings, and that every precaution to reduce stress must be taken. Reducing the number of transfers from holding buckets, use of green buckets to reduce stress, use of pure oxygen during all phases of recovery, and continual recirculation of water in holding tanks are some of the precautions that we believe will help to reduce stress and mortality.

Telemetry techniques (whether radio telemetry or hydrosonic telemetry) appear to be the best options for tracking the larger size classes (i.e., >107 mm/4.2 in FL) of subyearling chinook salmon. Based on beach seining activities conducted during this study, it appears that the larger-size subyearlings are difficult to capture along the shoreline areas. Mark and recapture techniques, which represent the only other feasible approach to estimating residence time, require the recapture of large numbers of tagged fish. Recapture techniques such as beach seining and electrofishing are not very effective in deep, offshore waters. The depth of the net operationally limits beach seines, which are typically 1.8 m (6.0 ft) deep, while the effective range of boat electrofishing equipment is approximately 2.4 m (8.0 ft).

7.2 MARK AND RECAPTURE TECHNIQUES

Salmonids smaller than about 107 mm are generally too small for radio telemetry techniques, given the current technology. These smaller fish are, however, of primary concern due to their apparent abundance in the study area and their tendency to occupy shallow water habitat. The only feasible option for estimating residence time of these smaller fish is some form of a mass mark and recapture approach. Mass marking/recapture involves the use of unique indicators to mark large batches of fish released at specific times and locations. These fish are then recaptured downriver of the point of release to determine the rate of travel and residence time between the release and recapture locations. The disadvantage of this method is that it requires an intensive recapture effort, individual fish cannot be tracked, and the resulting data cannot be used to visualize habitat use or behavior. However, mass marking methods do not limit minimum fish size and do not involve complicated surgical procedures. Several marking techniques suitable for mass marking subyearling chinook salmon are available.

Visible implant fluorescent elastomer (VIE) tags have been successfully used to mass mark outmigrant juvenile salmonids at rates approaching 400 fish/hr (Bailey *et al.* 1998). The VIE tagging method involves injecting a liquid polymer into transparent salmonid tissues, such as the adipose eyelid, which cures into a pliable, bio-compatible solid. Although the mark is internal, it is visible externally and will fluoresce under LED or UV light. This type of tag appears to have minimal impacts on survival, growth, and behavior of fish. The VIE tagging method has been successfully implemented in marking fishes with a FL as small as 8 mm (Malone *et al*. 1999).

Passive integrated transponders (PIT) tags have also been used to mark large numbers of fish on the Columbia River and allow the identification of individual fish. The PIT tag is an electronic tag 10 mm (0.39 in) long by 2.1 mm (0.08 in) in diameter that can be coded with one of 35 billion unique codes. These tags can be automatically detected and decoded *in situ*, eliminating the need to sacrifice or anesthetize fish during data retrieval. Laboratory studies with juvenile chinook salmon and steelhead show no adverse effect of the tag on growth and survival. Behavior tests show no significant effect of the tag on opercular rate, tail beat frequency, stamina, or post-fatigue survival in juvenile steelhead (Prentice *et al.* 1990). PIT tagging, however, can be costly and is only necessary when the study objectives require the identification of individual fish.

Perhaps the most inexpensive method to mass mark small (i.e., less then 107 mm/4.2 in FL) outmigrant juvenile salmonids is freeze branding. Freeze branding involves marking groups of fish with a unique identifier using a metal brand cooled with liquid nitrogen. This method is a quick and efficient way to mark fish. The marks or "brands" last for a month or more. Similar to VIE tags, these brands are externally visible and easily identified during recapture efforts. Researchers have used freeze branding routinely for many years as it provides for rapid recovery and is relatively unobtrusive.

If the determination of residence time in Portland Harbor remains the primary study objective, freeze branding or VIE tagging would be appropriate for use on the smaller fish (i.e., < 107 mm/4.2 in FL). However, if study objectives require individual tracking of small fish, PIT tagging may be necessary to collect such information. Due to bank conditions in Portland Harbor that preclude beach seine access in many areas, boat electrofishing is the best method of recovering tagged fish.

7.3 RESIDENCE TIME AND RATES OF TRAVEL

The radio telemetry data collected in May and June of 2001 indicate that subyearling fall Chinook salmon, 107 mm (4.2 in) to 125 mm (4.9 in) FL, move downriver through Portland Harbor in a few days. The average rate of downriver movement in the entire study area in May and June 2001 was 6.8 kpd (4.2 mpd) while the average rate of downriver movement in Portland Harbor was 4.6 kpd (2.8 mpd). Caution should be used in interpreting data from the small sample used in the 2001 study, because some of the fish observed did move faster through Portland Harbor than observed throughout the entire study area (Appendix D). As year-to-year variability in river conditions and the variability associated with fish size is largely unknown in the lower Willamette, further study of downriver movement is warranted to assure accurate and non-biased results.

We used the results of the 2001 study to approximate the sample size needed to estimate the mean rate of downriver movement using radio telemetry within an estimated error (B) of ± 1.6 kpd (1 mpd) at a 95 percent level of confidence. We calculated and used the sample variance (11.28 kpd/7.01 mpd) to approximate population variance (σ^2) based on the individual rates of downriver movement for the 16 fish used in the study area determinations. Using the equation:

$$n = \frac{z_{\alpha/2}^2 \sigma^2}{B^2}$$ (Harris *et al*. 1948)

we determined that a sample size of 27 fish would be required to obtain a statistically reliable estimate for radio-tagged fish in the lower Willamette River. However, given that only 37 percent of the released fish in our 2001 study provided suitable telemetry data and assuming a similar tracking efficiency in future studies, approximately 73 fish would need to be tagged and released. Because no data were collected for fish smaller than 107 mm (4.2 in) FL during the 2001 study effort, no estimate of variability was available for the determination of sample size relative to future mass marking efforts.

7.4 WATER QUALITY

Between May 25, 2001 and July 4, 2001, water temperature averaged 18.1°C within the study area, ranging from 16.0°C (60.8°F) to 20.6°C (69.1°F). High water temperatures may have exacerbated post-surgical stress on some of the radio-tagged fish, although no particular correlation was identified. The lower lethal limit for juvenile chinook salmon is 0.8°C (33.4°F) and the upper lethal limit for juvenile chinook salmon is 26.2°C (79.2°F, Spence *et al.* 1996). The temperature standard for the Willamette River and its tributaries, set by DEQ, is 20.0°C (68.0°F) year-round.

During our mobile tracking efforts, dissolved oxygen concentration averaged 8.1 ppm, ranging from 5.8 ppm to 9.8 ppm. The minimum DO range for coldwater species, including salmon and trout, is generally thought to be between 6.0 ppm as an absolute minimum and 8.0 ppm as a 30-day mean. At this level, juvenile anadromous and resident salmonids may rear with a low level of risk (Spence *et al.* 1996). During post-surgery holding periods, we found that low dissolved oxygen does adversely affect recovering fish. Providing O_2 into the holding pen containers through aeration stones appeared to significantly reduce post-surgical stress.

Published literature pertaining to the effects of turbidity on salmonids can be confusing and often conflicting. Responses observed are not only dependent on the amount of turbidity but are a function of life history stage, duration of exposure, concentration of suspended sediment, particle size, and angularity. Although moderate turbidity can provide fish cover from predation, high levels can reduce feeding efficiency, food availability, clog gillrakers, and erode gill filaments (Bruton 1985, Gregory *et al.* 1993). Turbidity levels during the 2001 mobile tracking operations ranged from 2.6 NTU to 13.7 NTU, well below levels that are known to affect salmonid behavior.

During the 2001 study effort, questions arose regarding the behavior of our radio-tagged fish in relation to dissolved oxygen concentrations and thermal stratification. Dissolved oxygen concentrations should be monitored at more frequent intervals and include the pre- and post-surgery holding periods. Fixed water quality stations could be used to monitor dissolved oxygen concentrations and temperature using automated devices at frequent intervals throughout the duration of the study. These fixed stations could be placed in the upper and lower study area on buoys.

As discussed in Section 6.0, our ability to detect a radio signal deteriorates as the transmitter is placed deeper in the water column. Given that radio-tagged fish may move into deeper water to find cooler water, thermal stratification should also be tested for and quantified at least once during each release. Such a test can be simply conducted using a water quality probe or by taking discrete samples at depth.

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APPENDIX A. PHOTOGRAPH LOG.

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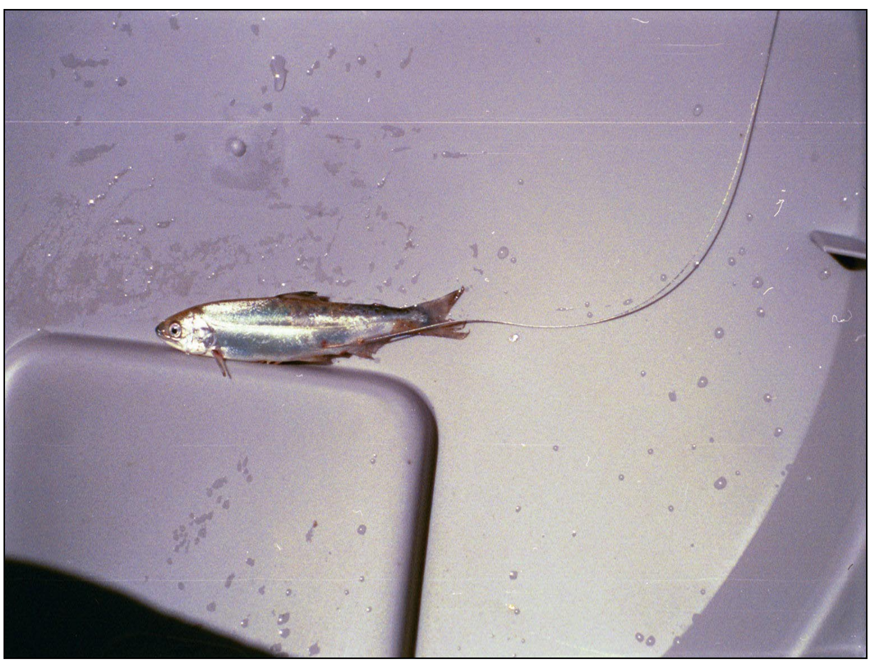
Photograph 1. T. M. Sullivan bypass facility guidance area.

Photograph 2. T. M. Sullivan bypass facility evaluation area.

Photograph 3. T. M. Sullivan bypass facility holding tanks.

Photograph 4. On-site surgery trailer in Milwaukee, Oregon.

Photograph 5. An anesthetized sub-yearling fall chinook in surgery.



Photograph 6. Radio tagged sub-yearling fall chinook (mortality).

Photograph 7. Mobile tracking boat and crew.

APPENDIX B. SURGERY AND RELEASE DATA.

APPENDIX B. SURGERY AND RELEASE DATA.

Release Number 1
Surgery Date: 5/24/2001
Release Date: 5/25/2001
Release Site: RM 12.2

FISH NO.	CHANNEL/CODE	FL (mm)	WEIGHT (g)	TAG WEIGHT RATIO (%)	MORTALITY	LOCATED
1	5/109	118	16.1	5.3	Y	NA
2	10/109	112	15.0	5.7	Y	NA
3	15/109	108	13.0	6.6	N	N
4	25/109	110	13.9	6.2	N	Y
5	5/110	113	16.0	5.4	Y	NA
6	10/110	115	15.8	5.4	N	Y
7	15/110	114	15.0	5.7	Y	NA
8	25/110	110	11.0	7.8	N	N
9	5/111	110	13.7	6.3	N	N
10	10/111	110	15.8	5.4	N	Y

Release Number 2
Surgery Date: 6/3/2001
Release Date: 6/4/2001
Release Site: RM 18.2

FISH NO.	CHANNEL/CODE	FL (mm)	WEIGHT (g)	TAG WEIGHT RATIO (%)	MORTALITY	LOCATED
1	5/112	115	14.5	5.9	N	Y
2	10/113	125	18.3	4.7	N	Y
3	15/112	112	14.4	6.0	N	Y
4	25/113	123	18.8	4.6	N	N
5	5/110	112	12.9	6.7	N	Y
6	10/112	116	16.5	5.2	Y	NA
7	15/111	118	15.9	5.4	N	N
8	25/112	108	12.6	6.8	N	N
9	5/109	128	21.9	3.9	N	N
10	10/109	108	12.0	7.2	N	Y
11	15/110	116	15.5	5.5	N	Y
12	25/111	107	12.7	6.8	Y	NA
13	5/108	106	12.5	6.9	Y	NA
14	10/108	107	11.3	7.6	N	Y
15	15/108	119	16.5	5.2	N	Y
16	25/107	113	14.2	6.1	N	Y
17	15/107	120	18.8	4.6	N	N
18	10/107	113	13.7	6.3	N	Y

Release Number 3
Surgery Date: 6/16/2001
Release Date: 6/17/2001
Release Site: RM 18.2

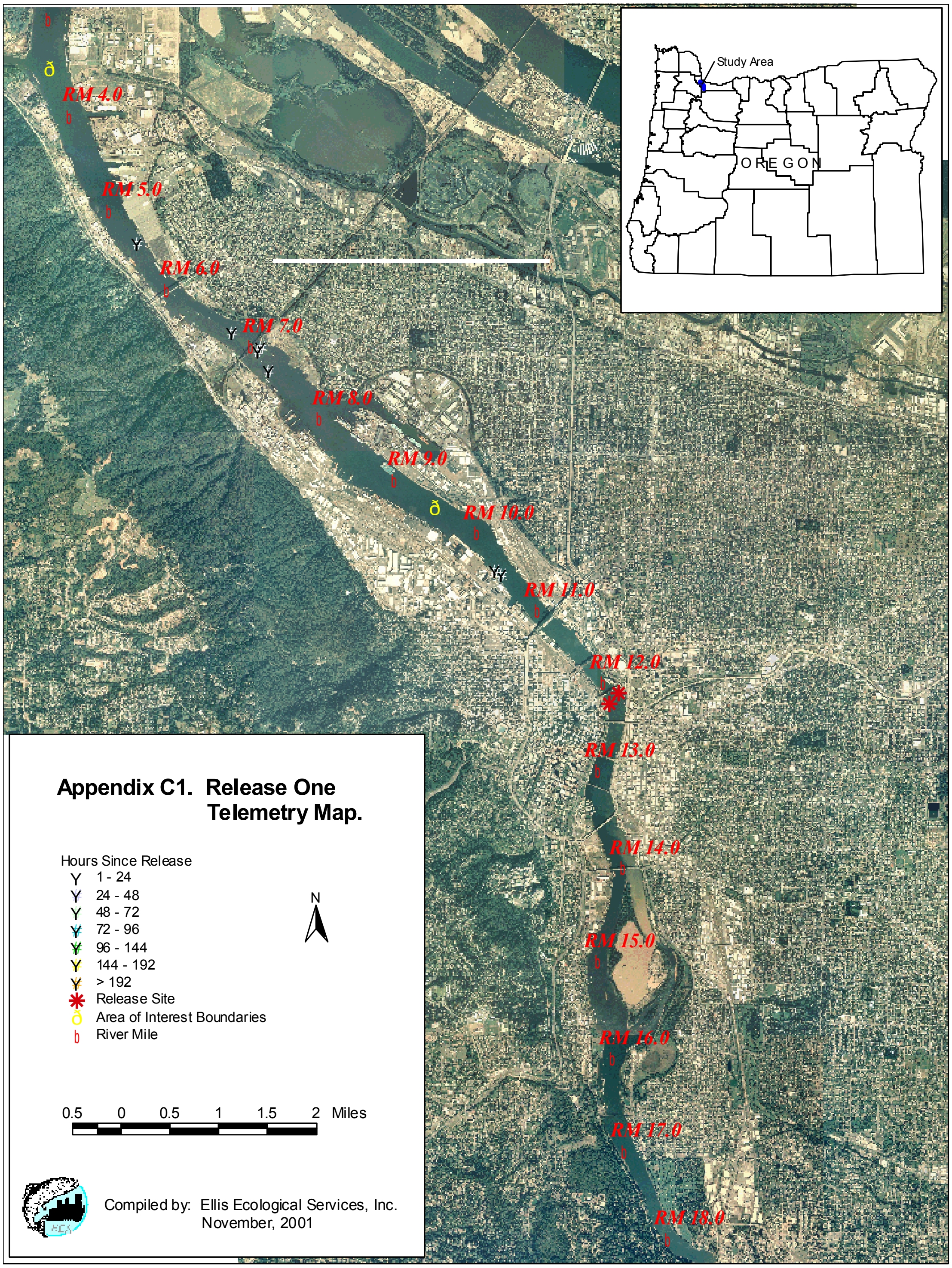
FISH NO.	CHANNEL/CODE	FL (mm)	WEIGHT (g)	TAG WEIGHT RATIO (%)	MORTALITY	LOCATED
1	15/115	103	13.4	6.4	N	Y
2	10/117	110	16.9	5.1	Y	NA
3	10/116	100	12.1	7.1	Y	NA
4	5/115	106	12.4	6.9	N	N
5	15/114	109	15.2	5.7	N	Y
6	25/114	122	19.1	4.5	N	Y
7	5/107	119	18.0	4.8	N	Y
8	15/117	112	15.4	5.6	Y	NA
9	10/114	117	16.0	5.4	N	N
10	5/114	110	13.4	6.4	N	Y
11	15/116	152	33.7	2.6	N	N
12	25/108	110	14.3	6.0	Y	NA
13	5/113	116	14.5	5.9	N	Y
14	10/115	107	13.4	6.4	N	N
15	15/113	105	16.3	5.3	N	Y
16	10/112	118	16.9	5.1	Y	NA
17	5/108	118	16.5	5.2	N	Y
18	15/118	112	15.6	5.5	N	N

Release Number 3
Surgery Date: 6/23/2001
Release Date: 6/24/2001
Release Site: RM 18.2

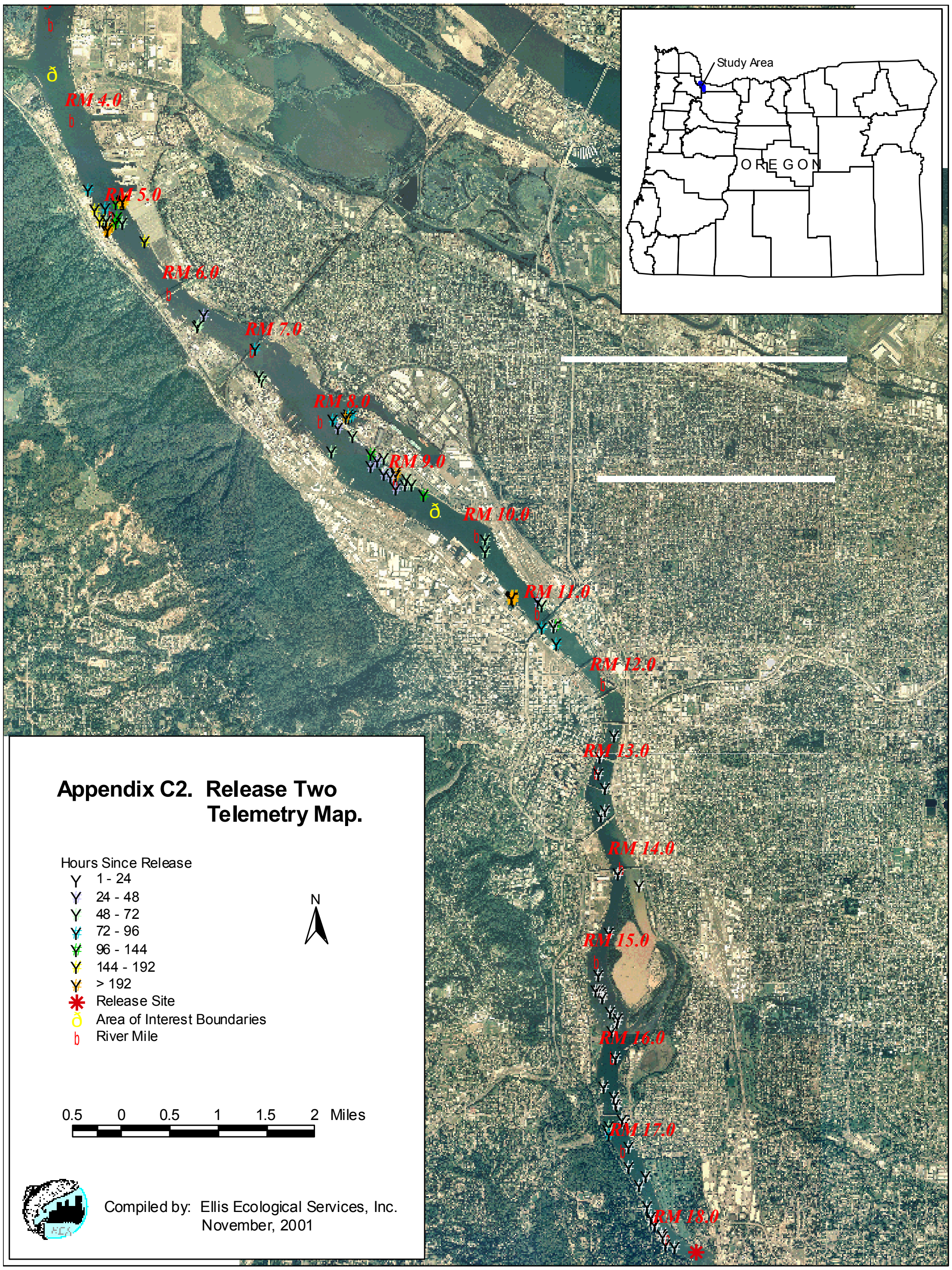
FISH NO.	CHANNEL/CODE	FL (mm)	WEIGHT (g)	TAG WEIGHT RATIO (%)	MORTALITY	LOCATED
1	15/115	110	12.8	6.7	N	Y
2	25/108	112	14.6	5.9	N	Y
3	15/117	111	13.9	6.2	N	Y
4	10/115	116	15.9	5.4	N	N
5	5/108	110	12.9	6.7	N	Y
6	10/116	120	14.9	5.8	N	Y
7	10/117	121	16.4	5.2	N	Y
8	5/115	115	16.8	5.1	N	N
9	10/112	110	13.6	6.3	N	Y

APPENDIX C. RADIO TELEMETRY MAPS.

APPENDIX C. TELEMETRY DATA MAPS.



Appendix C1. Release One Telemetry Map.



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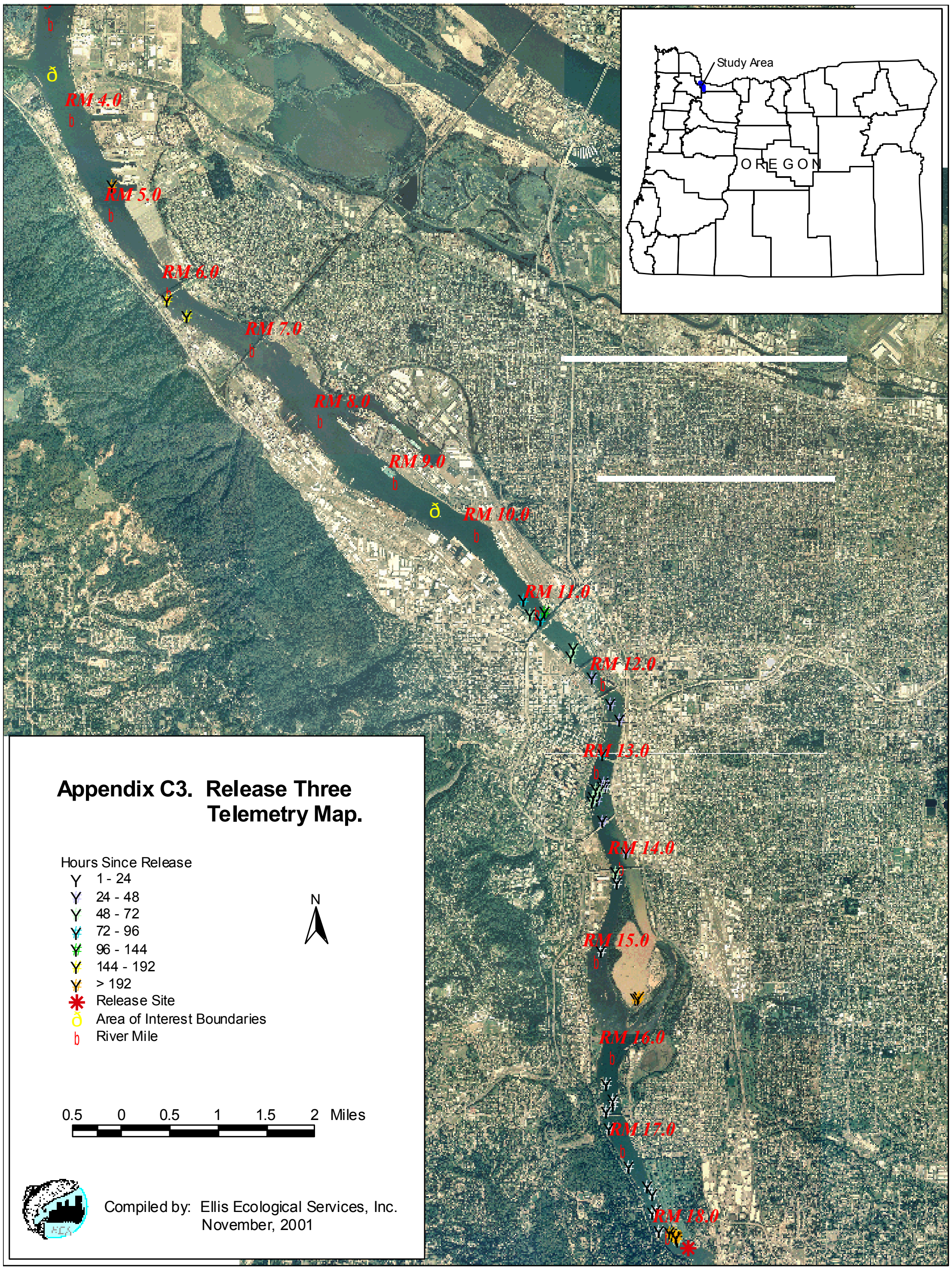
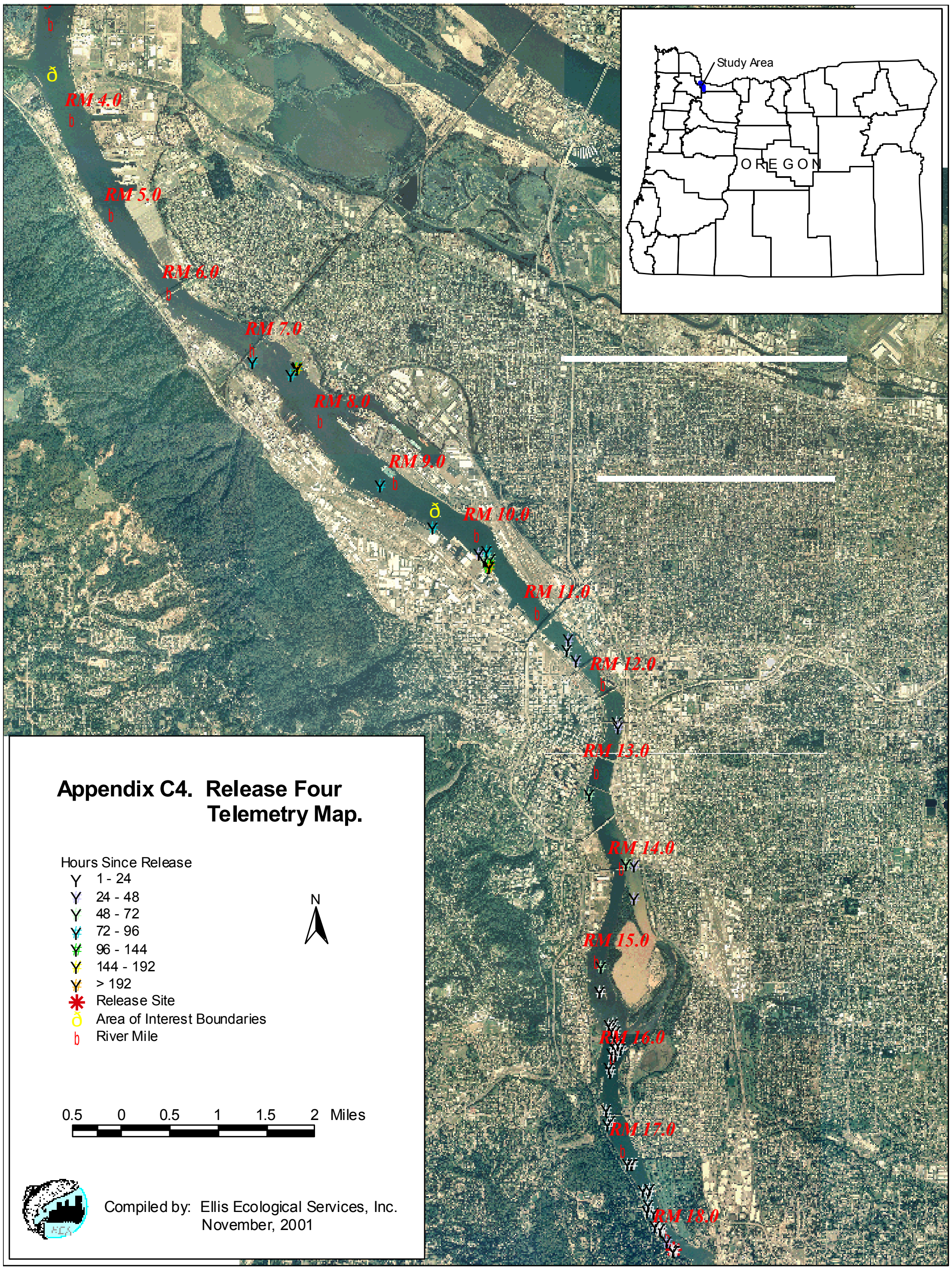
This document is currently under review by US EPA and its federal, state and tribal partners, and is subject to change in whole or in part.


Appendix C3. Release Three Telemetry Map.
Hours Since Release
1 - 24
24 - 48
48 - 72
72 - 96
96 - 144
144 - 192
> 192
Release Site
Area of Interest Boundaries
River Mile
N
0.5 0 0.5 1 1.5 2 Miles
Compiled by: Ellis Ecological Services, Inc.
November, 2001
Study Area
OREGON
RM 4.0
RM 5.0
RM 6.0
RM 7.0
RM 8.0
RM 9.0
RM 10.0
RM 11.0
RM 12.0
RM 13.0
RM 14.0
RM 15.0
RM 16.0
RM 17.0
RM 18.0


Appendix C4. Release Four Telemetry Map.
Hours Since Release
1 - 24
24 - 48
48 - 72
72 - 96
96 - 144
144 - 192
> 192
Release Site
Area of Interest Boundaries
River Mile
N
0.5 0 0.5 1 1.5 2 Miles
Compiled by: Ellis Ecological Services, Inc.
November, 2001
Study Area
OREGON
RM 4.0
RM 5.0
RM 6.0
RM 7.0
RM 8.0
RM 9.0
RM 10.0
RM 11.0
RM 12.0
RM 13.0
RM 14.0
RM 15.0
RM 16.0
RM 17.0
RM 18.0

APPENDIX D. POST RELEASE MOVEMENTS OF RADIO-TAGGED SUBYEARLING CHINOOK SALMON.

APPENDIX D. POST RELEASE MOVEMENTS OF RADIO-TAGGED SUBYEARLING CHINOOK SALMON.

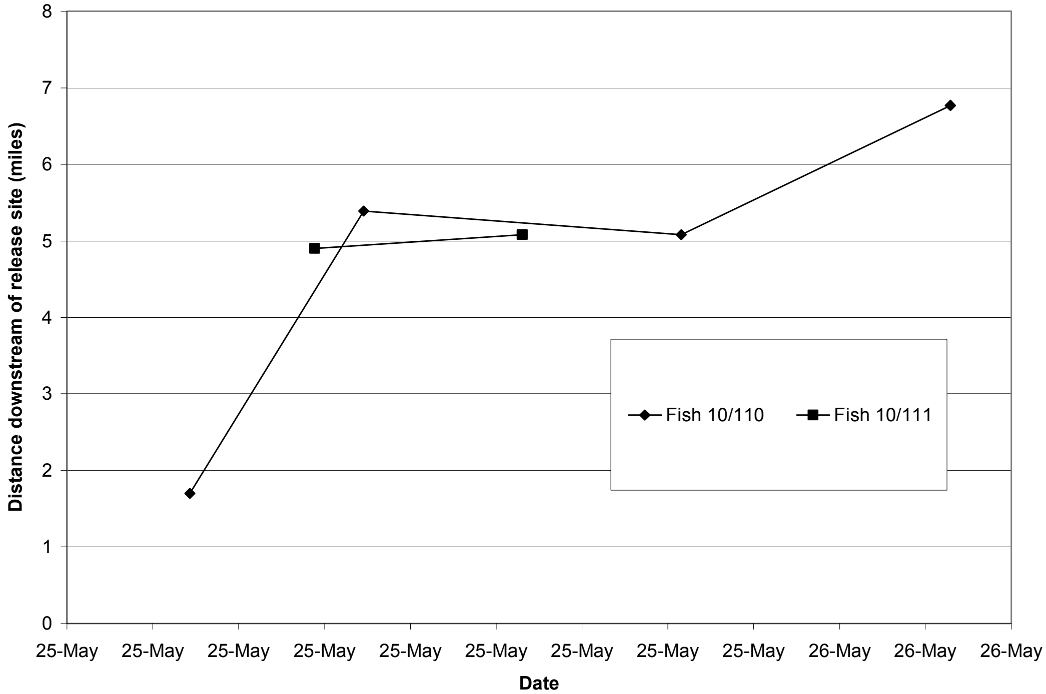


Figure D1. Post-release movement of two, release one fish.

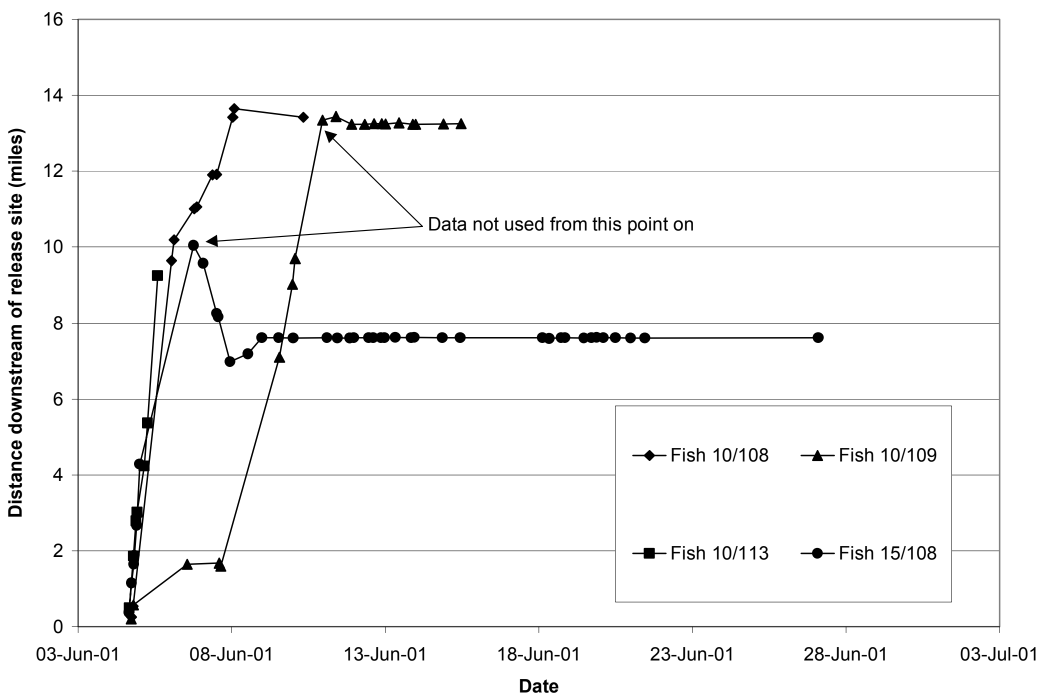


Figure D2. Post-release movement of four, release two fish.

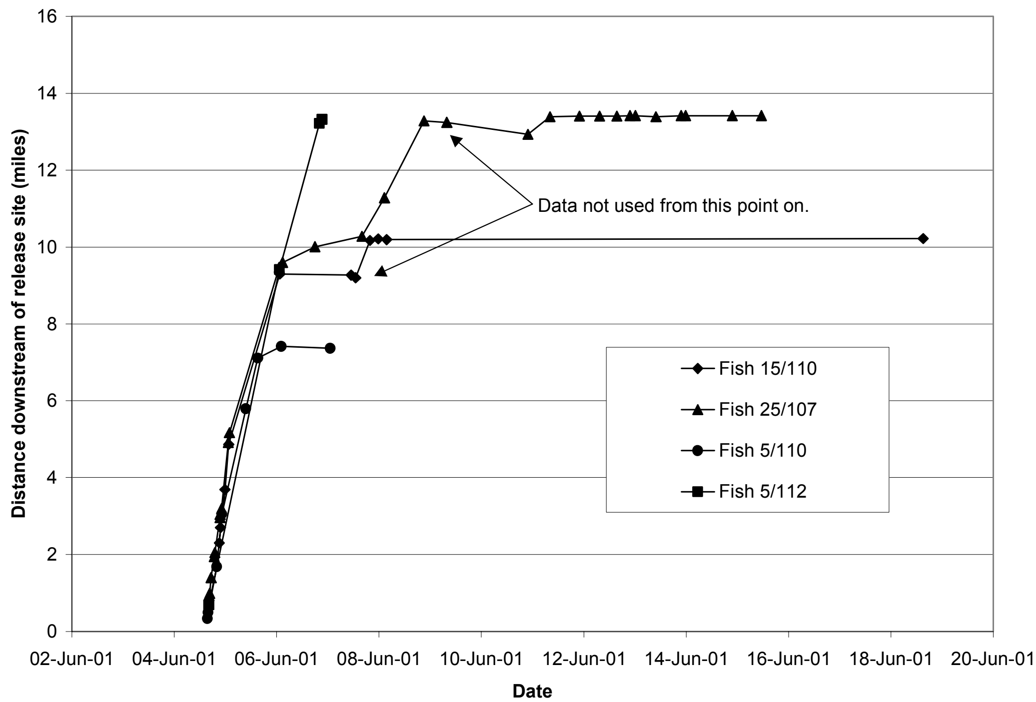


Figure D3. Post-release movement of four additional release two fish.

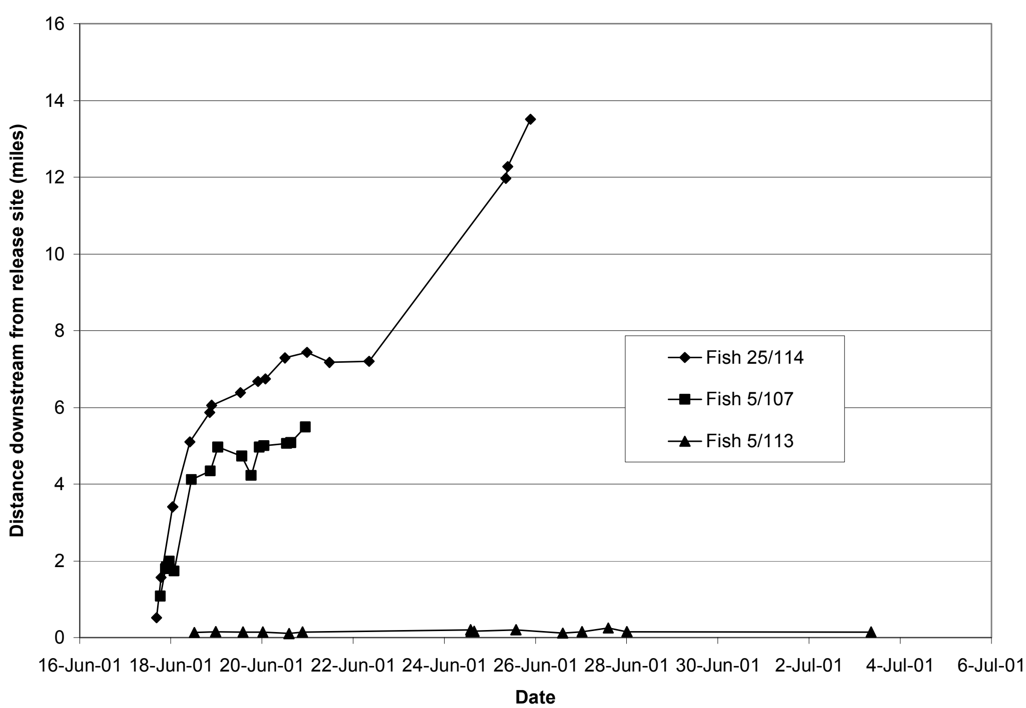


Figure D4. Post-release movement of three, release three fish.

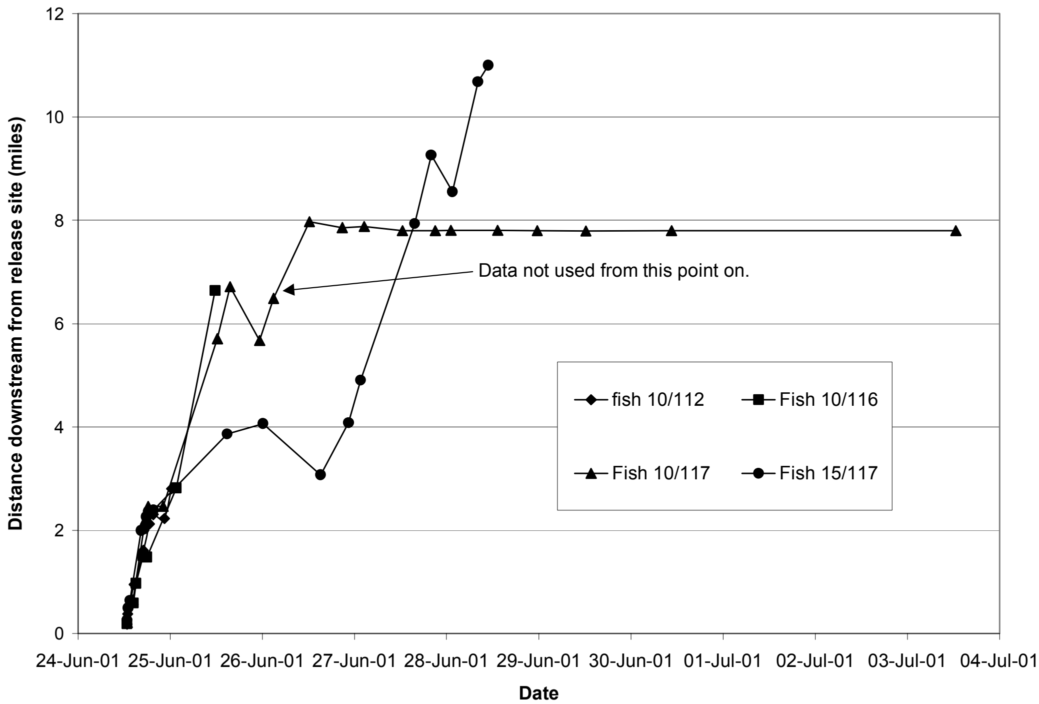


Figure D5. Post-release movements of four, release four fish.